Booster Multipole Corrector

V.S.Kashikhin, Meeting December 14, 2004

Magnet specification with 0.2 m effective length are shown in the Table 1.

Table 1

Type	Integrated field/gradient	Aperture field/gradient	Field at 1" radius	Max slew rate
Horizontal dipole	0.009 T-m	0.045 T	0.045 T	0.5 T-m/s
Vertical dipole	0.015 T-m	0.075 T	0.075 T	0.8 T-m/s
Normal quadrupole	0.08 T	0.4 T/m	0.01016 T	160 T/s
Skew quadrupole	0.008 T	0.04 T/m	0.001016 T	0.8 T/s
Normal sextupole	1.41 T/m	7.05 T/m^2	0.00455 T	2800T/m/s
Skew sextupole	1.41 T/m	7.05 T/m^2	0.00455 T	2800T/m/s

Calculated values at 200 A current, 0.2 m core and effective length.

Table 2

Type	Integrated field/gradient	Aperture field/gradient	Inductance, uH	Max inductive voltage, V
Horizontal dipole	0.0108 T-m	0.045 T	490	6
Vertical dipole	0.0108 T-m	0.054 T	490	6
Normal quadrupole	0.075 T	0.375 T/m	69	28
Skew quadrupole	0.022 T	0.11 T/m	4	0.1
Normal sextupole	1.56 T/m	7.8 T/m^2	110	44
Skew sextupole	1.56 T/m	7.8 T/m^2	110	44

This magnet has both normal and skew windings to generate dipole, quadrupole, and sextupole magnetic field components.

The magnet coils are wound into the slots of an iron core and have a water cooling. The hollow copper conductor of type 6835, Outokumpu is used for all coils. The conductor has dimensions 6 mm x 6 mm and 4 mm hole diameter. The slot dimension was chosen to place needed number of conductors with effective turn-to-turn insulation (0.5 mm) and 2 mm thick ground insulation.

The 60 turns dipole winding has the longest water cooling circuit and can be cooled using 4 atm water pressure drop providing 1.2 l/min flow. The water temperature rise at 200 A DC is only 13 C°. All other windings are shorter and their cooling can be combined in the effective way. It should be noted that duty cycle most of windings not exceed 50 %.
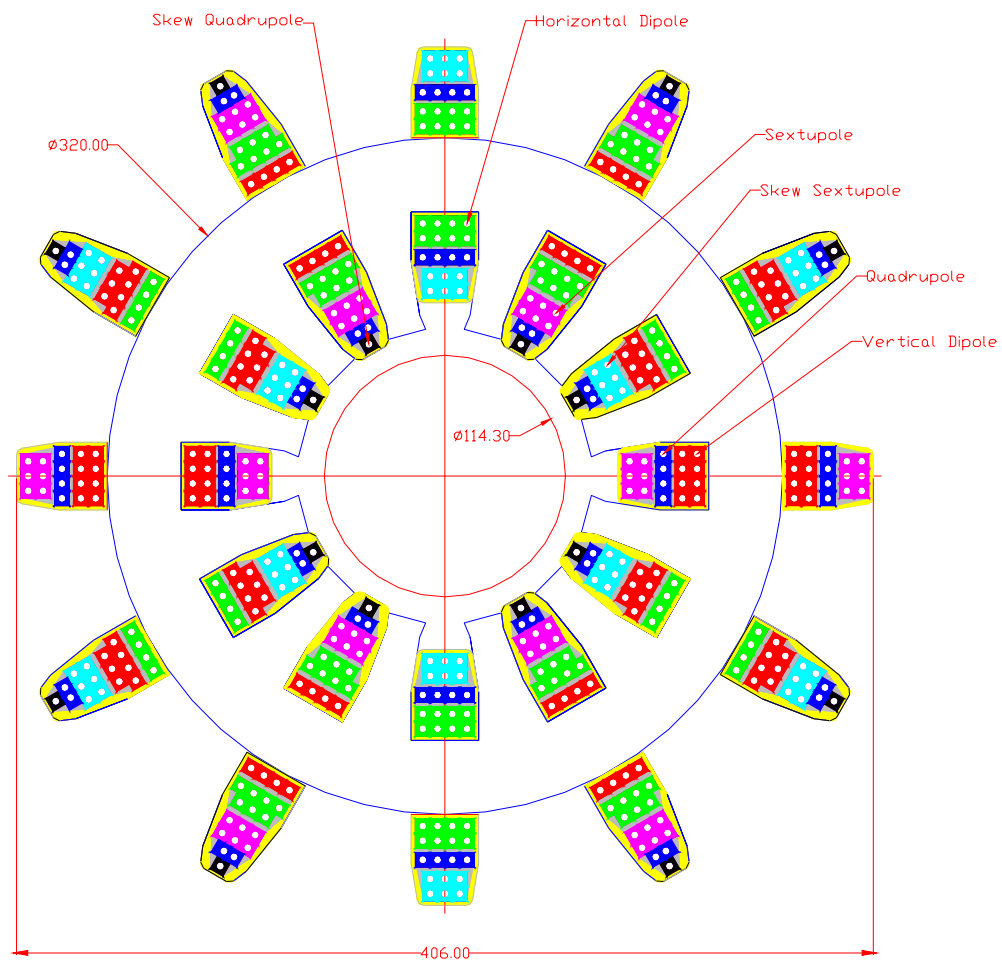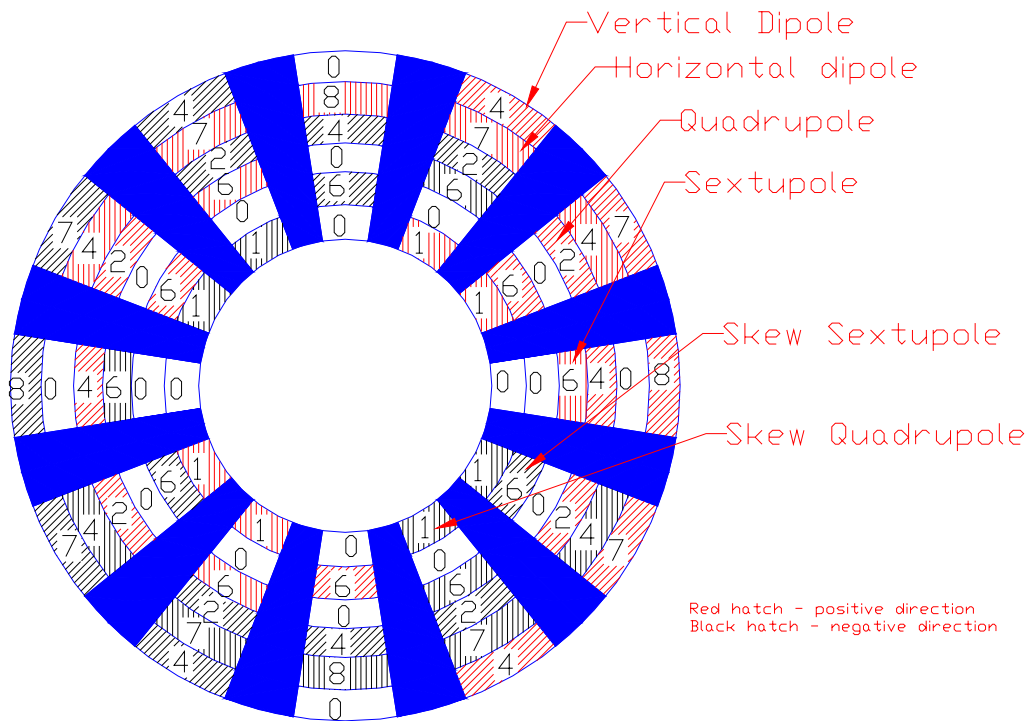
Fig. 1. Magnet cross-section

Vertical Dipole
Horizontal dipole
Quadrupole
Sextupole
Skew Sextupole
Skew Quadrupole

Red hatch – positive direction
Black hatch – negative direction

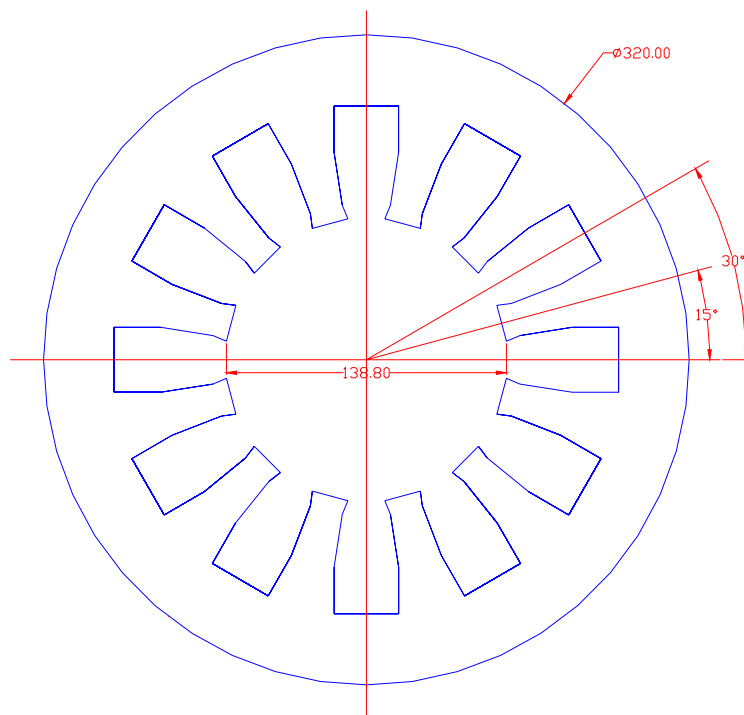Fig. 2. Number of turns in the slots

⌀320.00
30°
15°
138.80

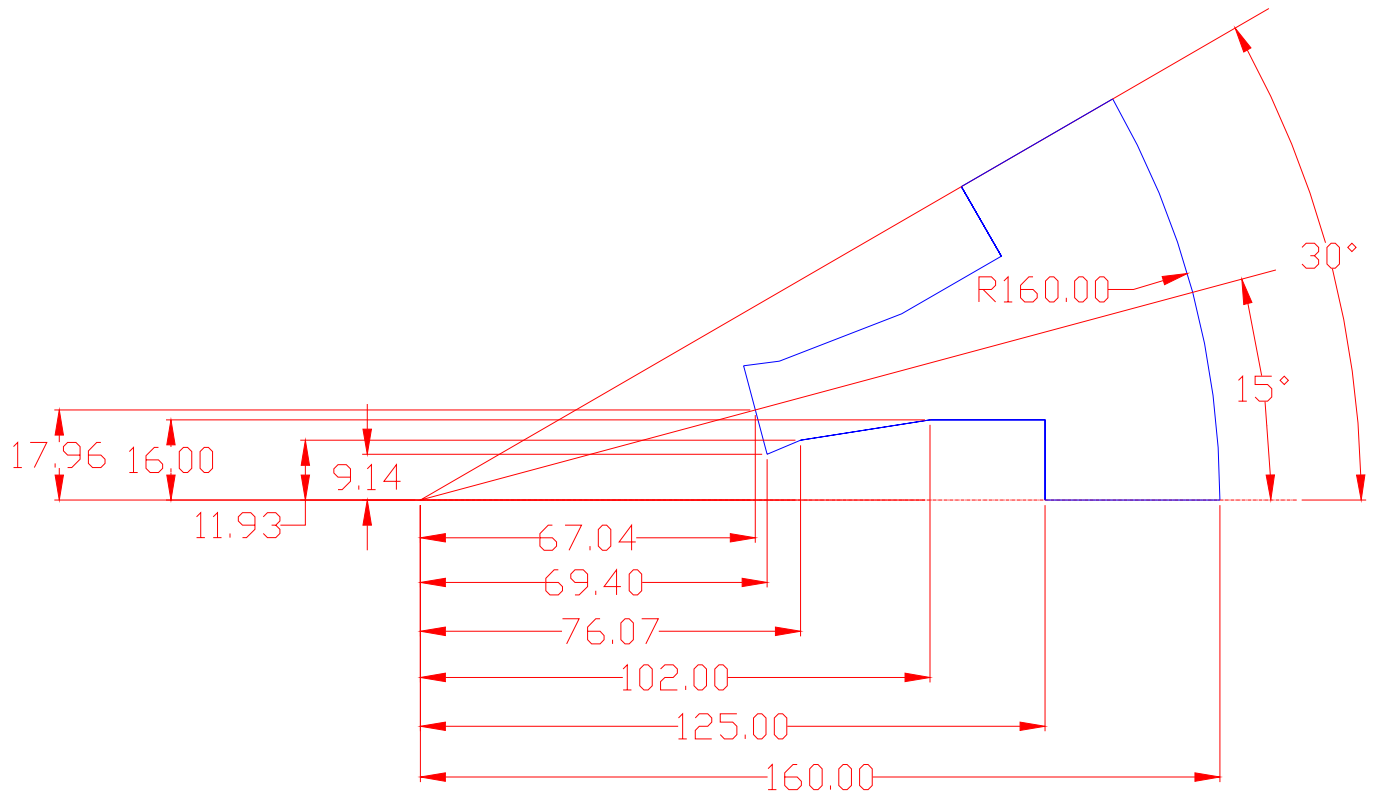Fig. 3. The iron yoke cross-section

Fig. 4. The lamination dimensions

The iron core made from stamped laminations. The lamination should have an electrical insulation. Because the quadrupole field component should be switched with 500 Hz frequency, the recommended lamination steel thickness should be ~ 0.2 mm.
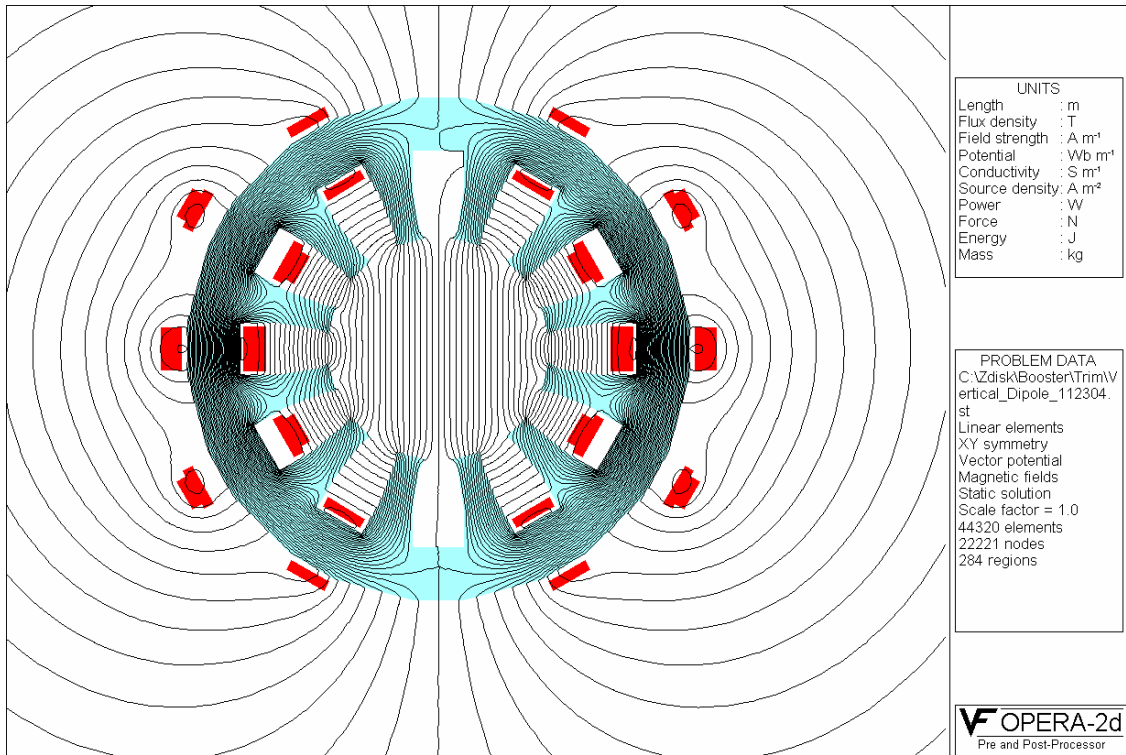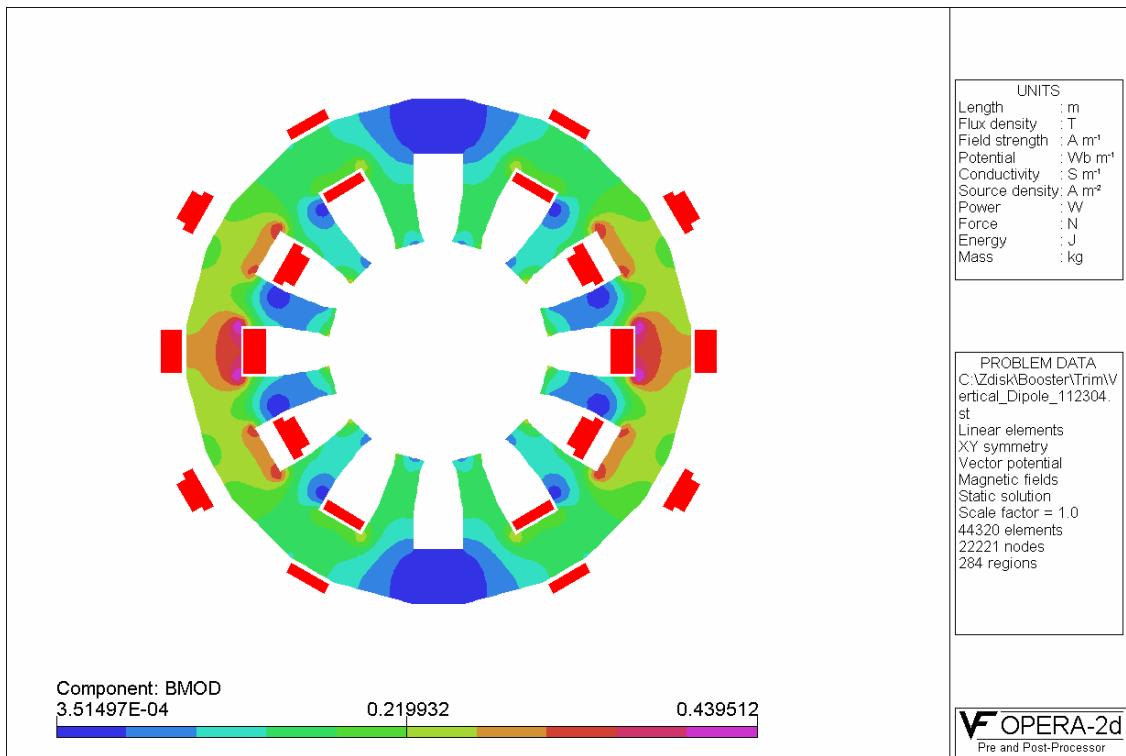
Fig. 5. The vertical dipole flux lines.

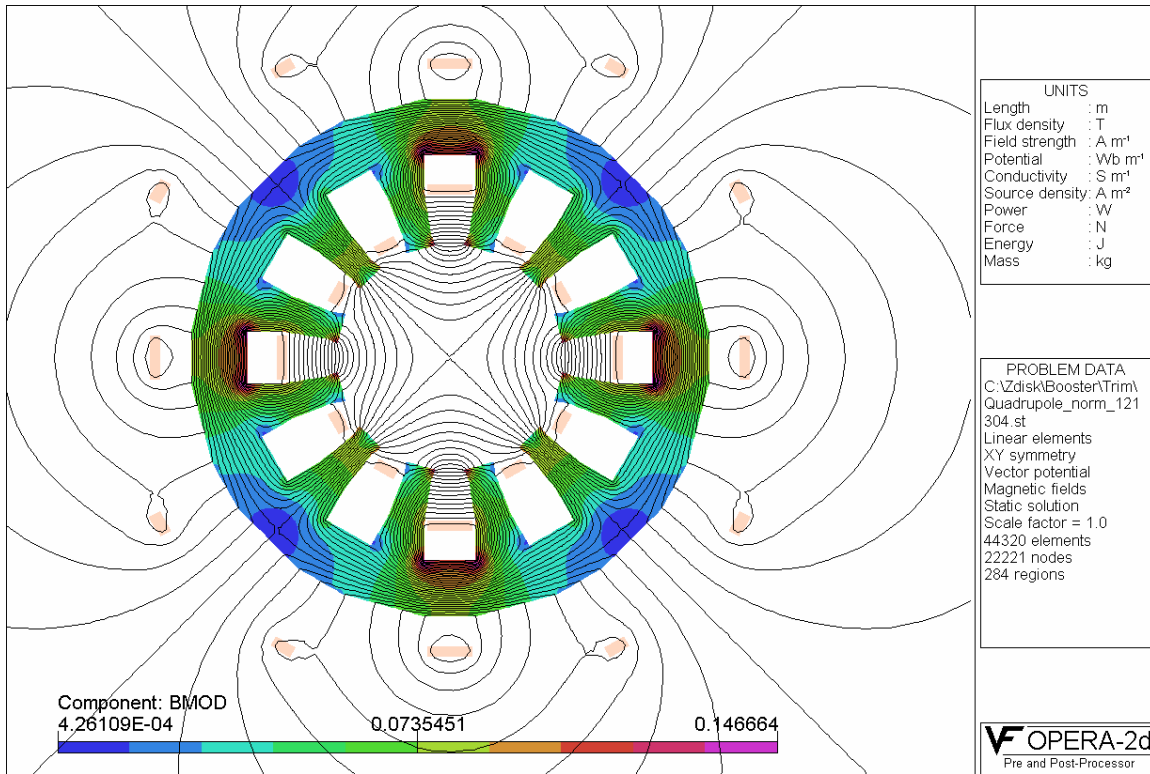Fig. 6. The vertical dipole yoke flux density.

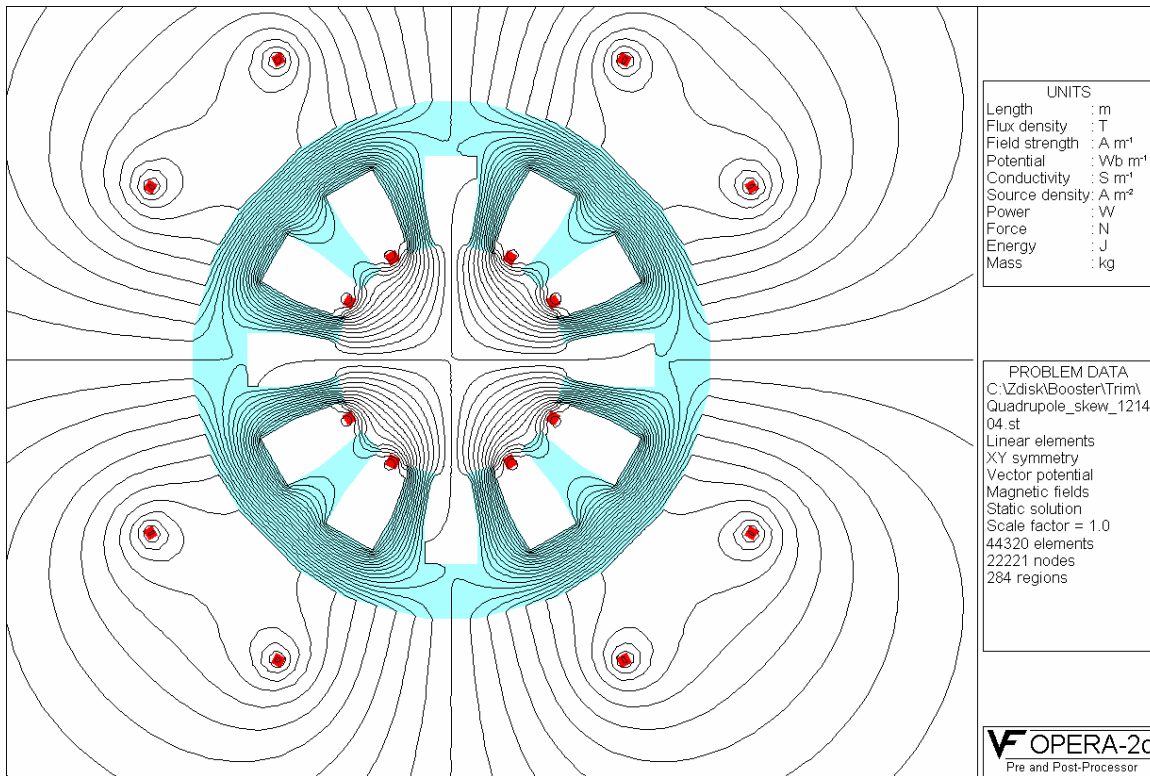Fig. 7. The normal quadrupole flux lines and flux density.
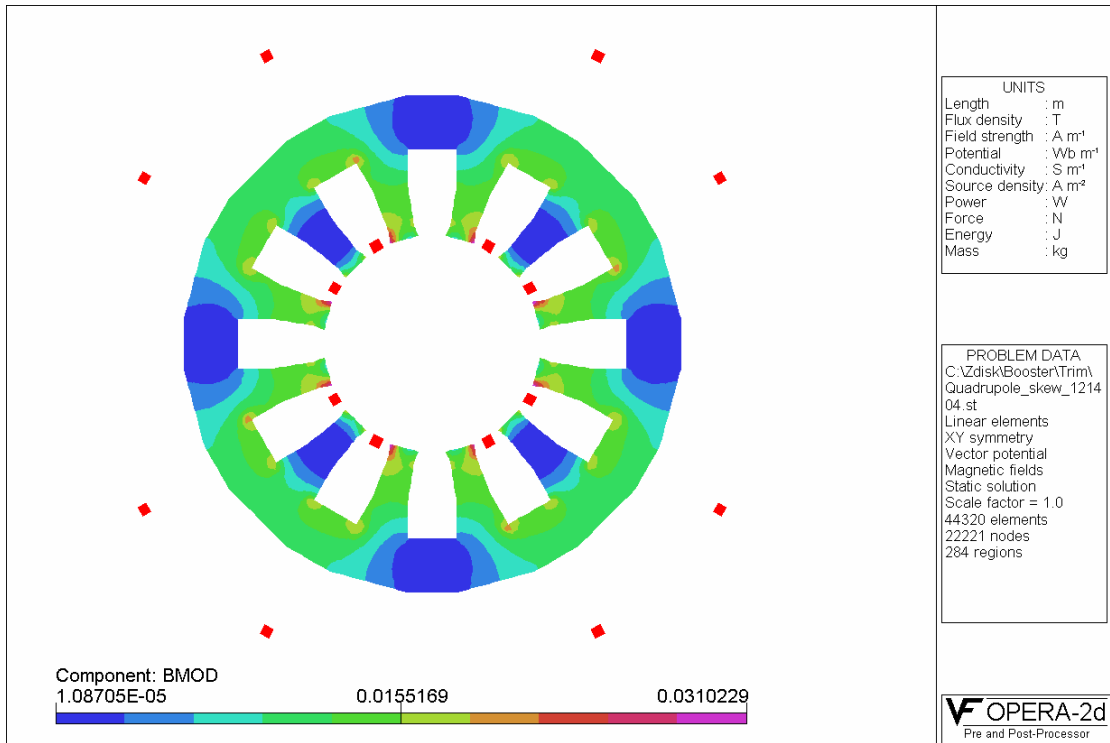
Fig. 8. The skew quadrupole flux lines.

Fig. 9. The skew quadrupole yoke flux density.

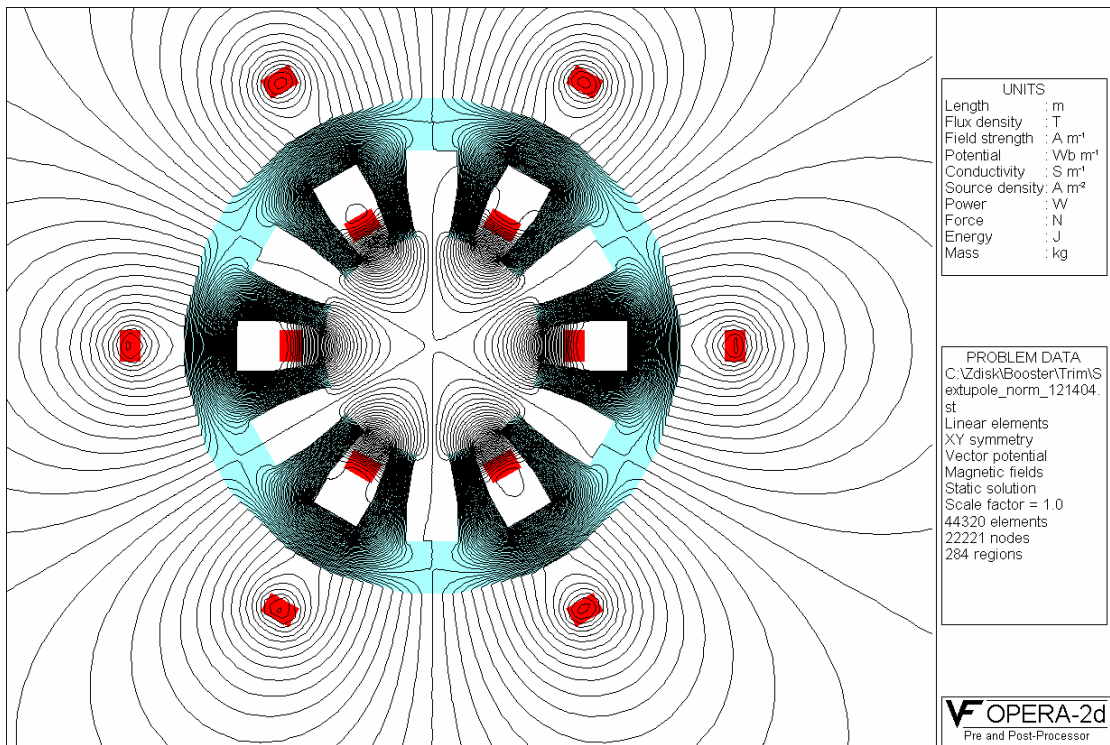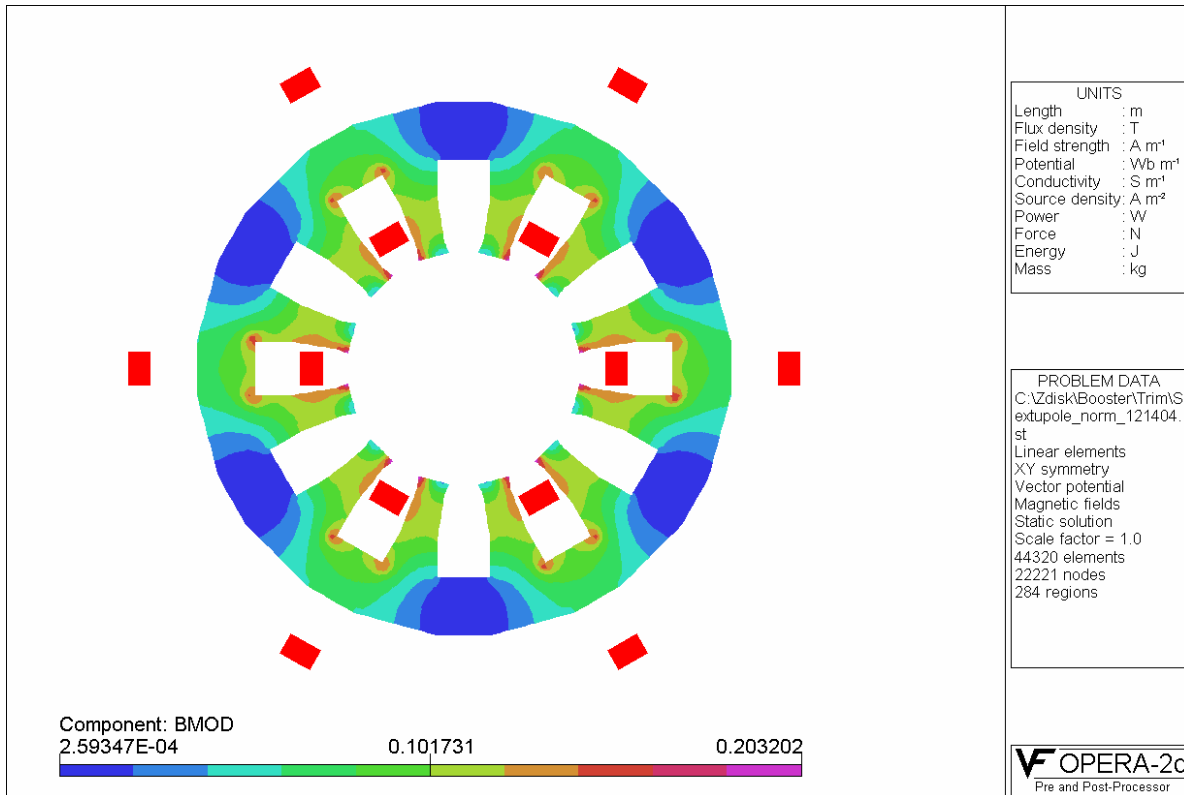Fig. 10. The normal sextupole flux lines.

Fig. 11. The normal sextupole yoke flux density.

Summary

The proposed corrector is capable to generate all combinations of specified magnetic fields. The iron yoke extremely reduce the magnet effective air gap. The hollow conductor provides an effective water cooling. The low number of turns at reasonable 200 A current reduces the maximum voltage.

The effective length of each field component should be carefully estimated using 3D approach.

The maximum flux density in the yoke at 200 A in all windings is only 0.8 T. But the end fields and eddy currents will increase this value.